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Kusumoto

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(54) **CONTROL APPARATUS, COMMUNICATION SYSTEM, COMMUNICATION METHOD, AND PROGRAM**

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H04L 12/24 (2006.01)
(Continued)

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CPC ***H04L 41/0826*** (2013.01); ***H04L 12/185*** (2013.01); ***H04L 45/16*** (2013.01); ***H04L 49/70*** (2013.01); ***H04L 69/14*** (2013.01); *H04L 45/245* (2013.01); *Y02B 60/33* (2013.01)

(58) **Field of Classification Search**
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USPC 370/228, 216, 229, 235, 254, 252
See application file for complete search history.

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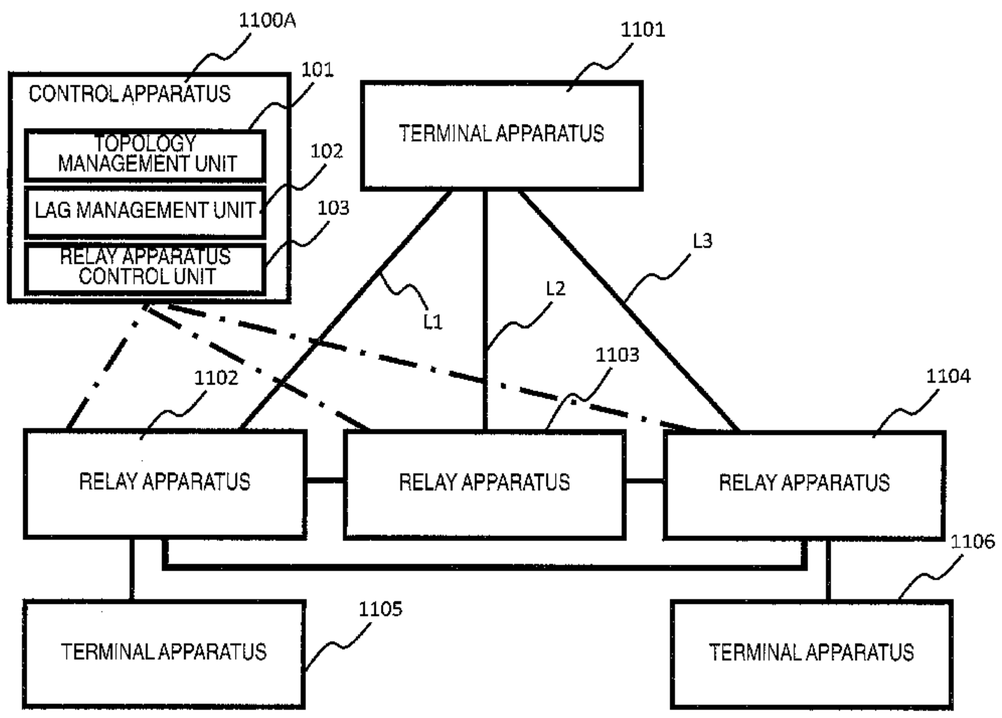
Primary Examiner — Dady Chery
(74) *Attorney, Agent, or Firm* — Finnegan, Henderson, Farabow, Garrett & Dunner LLP

(57) **ABSTRACT**

A control apparatus includes: a topology management unit that manages a network topology formed by including a plurality of relay apparatuses; a link aggregation group management unit that groups ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology and manages the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node; and a relay apparatus control unit that controls the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packet are not forwarded to the physical links that form the virtual logical link.

12 Claims, 16 Drawing Sheets



(51) **Int. Cl.**

H04L 12/761	(2013.01)
H04L 12/18	(2006.01)
H04L 29/06	(2006.01)
H04L 12/931	(2013.01)
H04L 12/709	(2013.01)

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Nick McKeown and seven other authors, "OpenFlow: Enabling Innovation in Campus Networks," [online], [Searched on Jan. 11, 2012], Internet <URL:http://www.openflow.org/documents/openflow-wp-latest.pdf>.

"OpenFlow Switch Specification," Version 1.1.0 Implemented (Wire Protocol 0x02), [online] [Searched on Jan. 11, 2012], Internet <URL:http://www.openflow.org/documents/openflow-spec-v1.1.0.pdf>.

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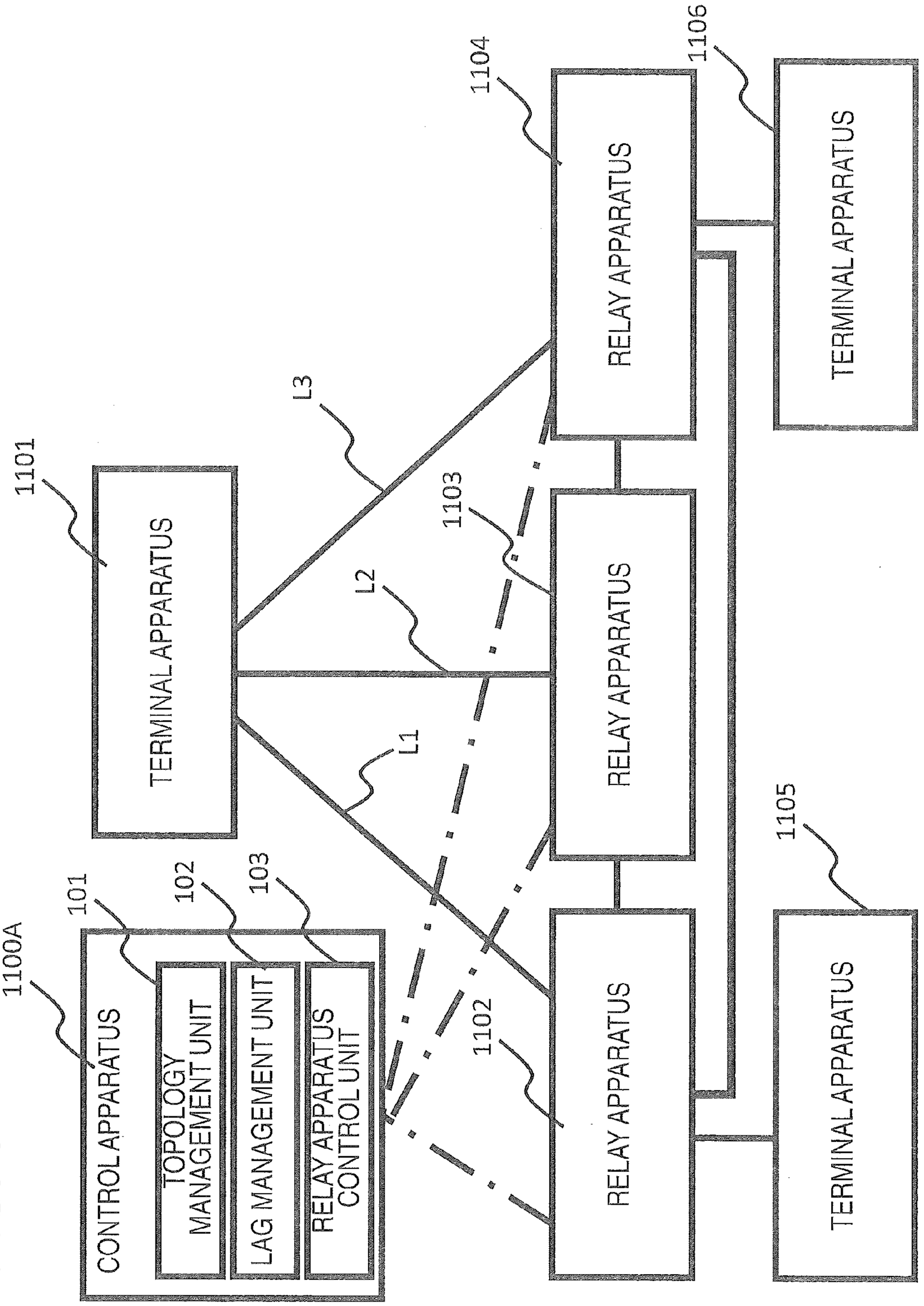
FIG. 1


1100A
CONTROL APPARATUS
101
TOPOLOGY MANAGEMENT UNIT
102
LAG MANAGEMENT UNIT
103
RELAY APPARATUS CONTROL UNIT
1101
TERMINAL APPARATUS
1102
RELAY APPARATUS
1103
RELAY APPARATUS
1104
RELAY APPARATUS
1105
TERMINAL APPARATUS
1106
TERMINAL APPARATUS
L1
L2
L3

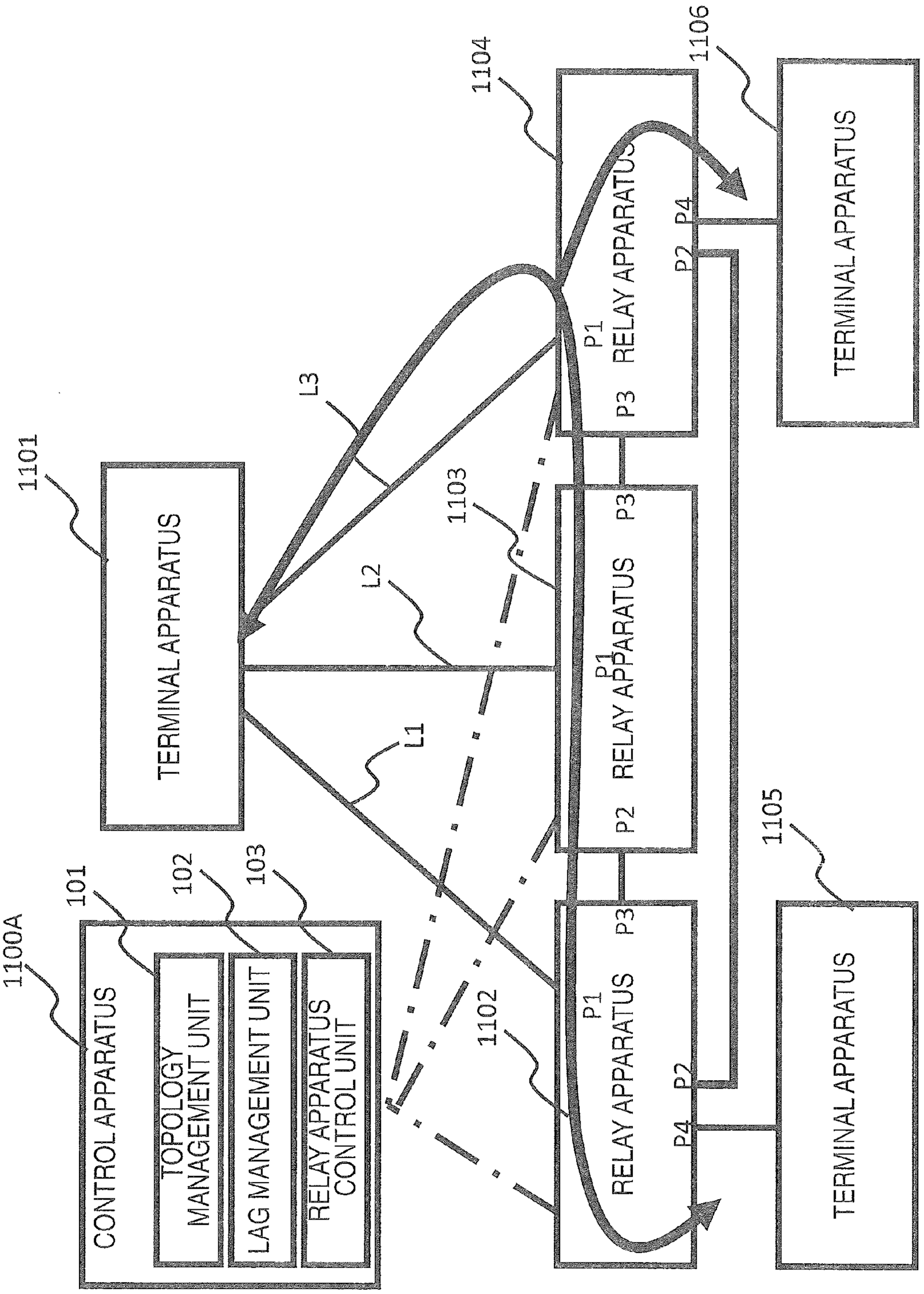

1100A
CONTROL APPARATUS
TOPOLOGY MANAGEMENT UNIT
LAG MANAGEMENT UNIT
RELAY APPARATUS CONTROL UNIT
101
102
103
1101
TERMINAL APPARATUS
1102
RELAY APPARATUS
P1
P2
P3
P4
1103
RELAY APPARATUS
1104
RELAY APPARATUS
1105
TERMINAL APPARATUS
1106
TERMINAL APPARATUS
L1
L2
L3

FIG. 2

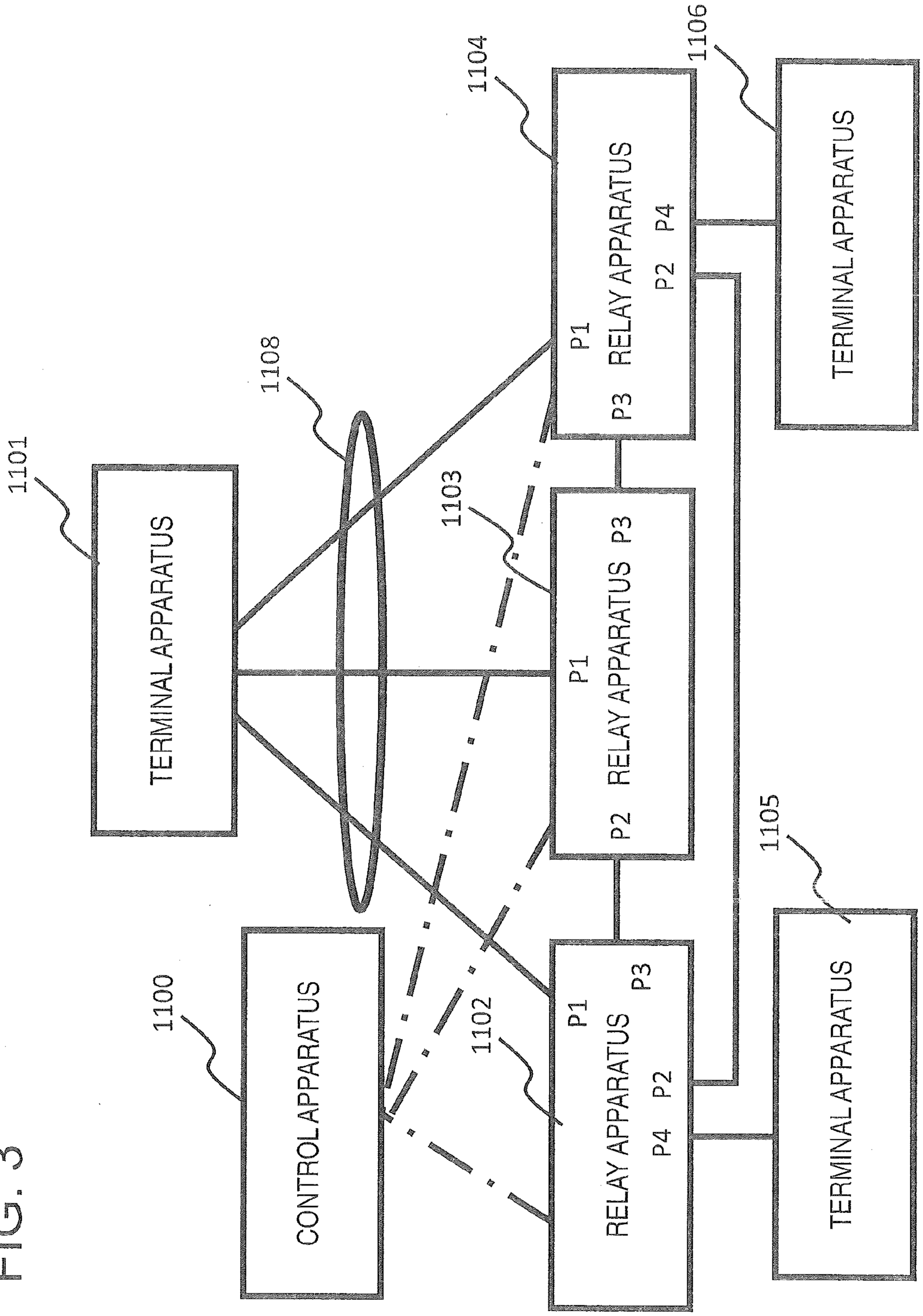

1104
1106
1101
1108
1103
1105
1100
1102
TERMINAL APPARATUS
CONTROL APPARATUS
RELAY APPARATUS
P1
P2
P3
P4

FIG. 3

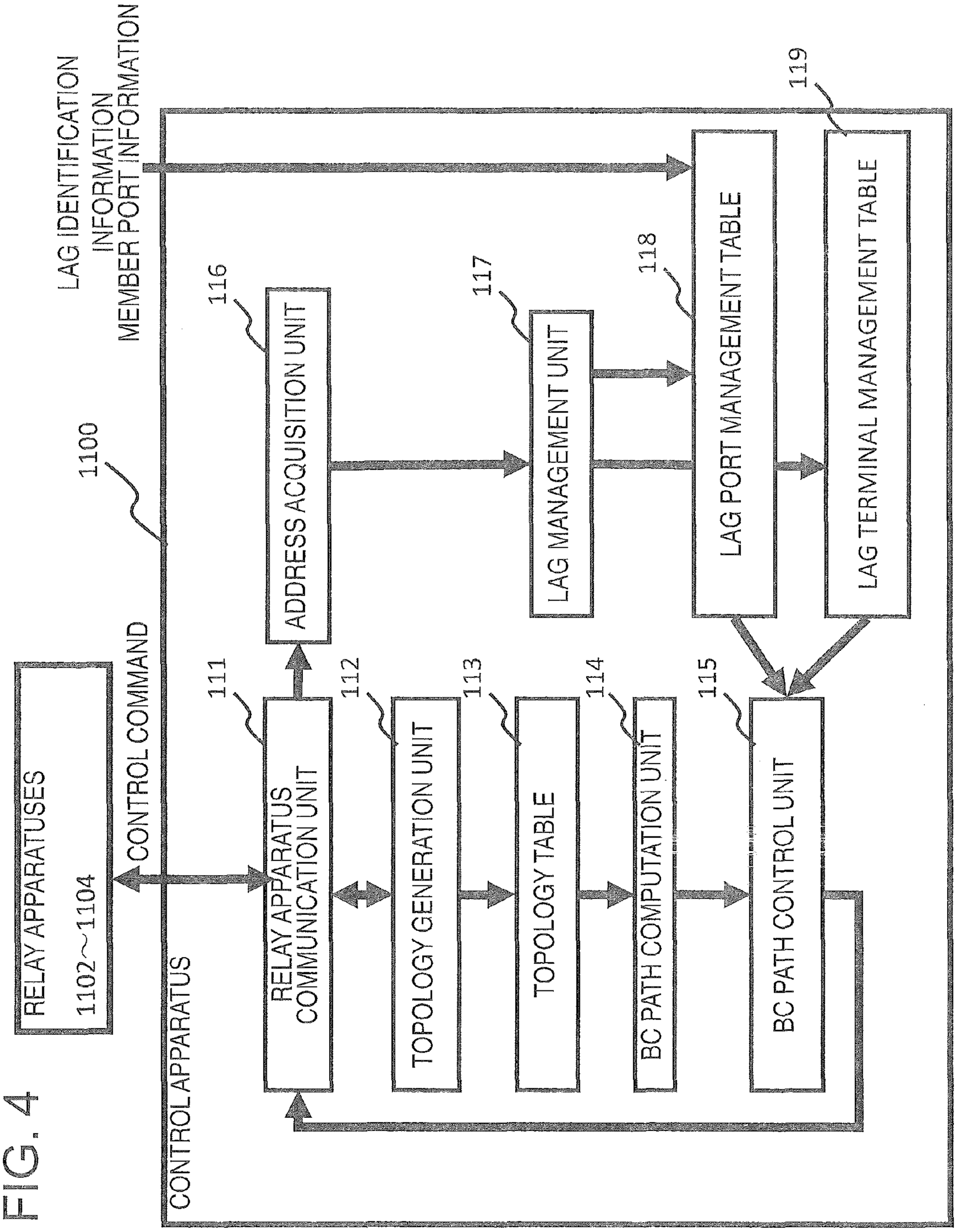

CONTROL APPARATUS
RELAY APPARATUS
1102~1104
CONTROL COMMAND
1100
LAG IDENTIFICATION INFORMATION
MEMBER PORT INFORMATION
RELAY APPARATUS COMMUNICATION UNIT
111
ADDRESS ACQUISITION UNIT
116
TOPOLOGY GENERATION UNIT
112
TOPOLOGY TABLE
113
BC PATH COMPUTATION UNIT
114
BC PATH CONTROL UNIT
115
LAG MANAGEMENT UNIT
117
LAG PORT MANAGEMENT TABLE
118
LAG TERMINAL MANAGEMENT TABLE
119

FIG. 4

RELAY APPARATUS INFORMATION	PORT INFORMATION	ADJACENT RELAY APPARATUS	ADJACENT PORT INFORMATION
1102	P1	NONE	NONE
1102	P2	1104	P2
1102	P3	1103	P3
:	:	:	:
1103	P1	NONE	NONE
:	:	:	:
1104	P1	NONE	NONE

FIG. 5

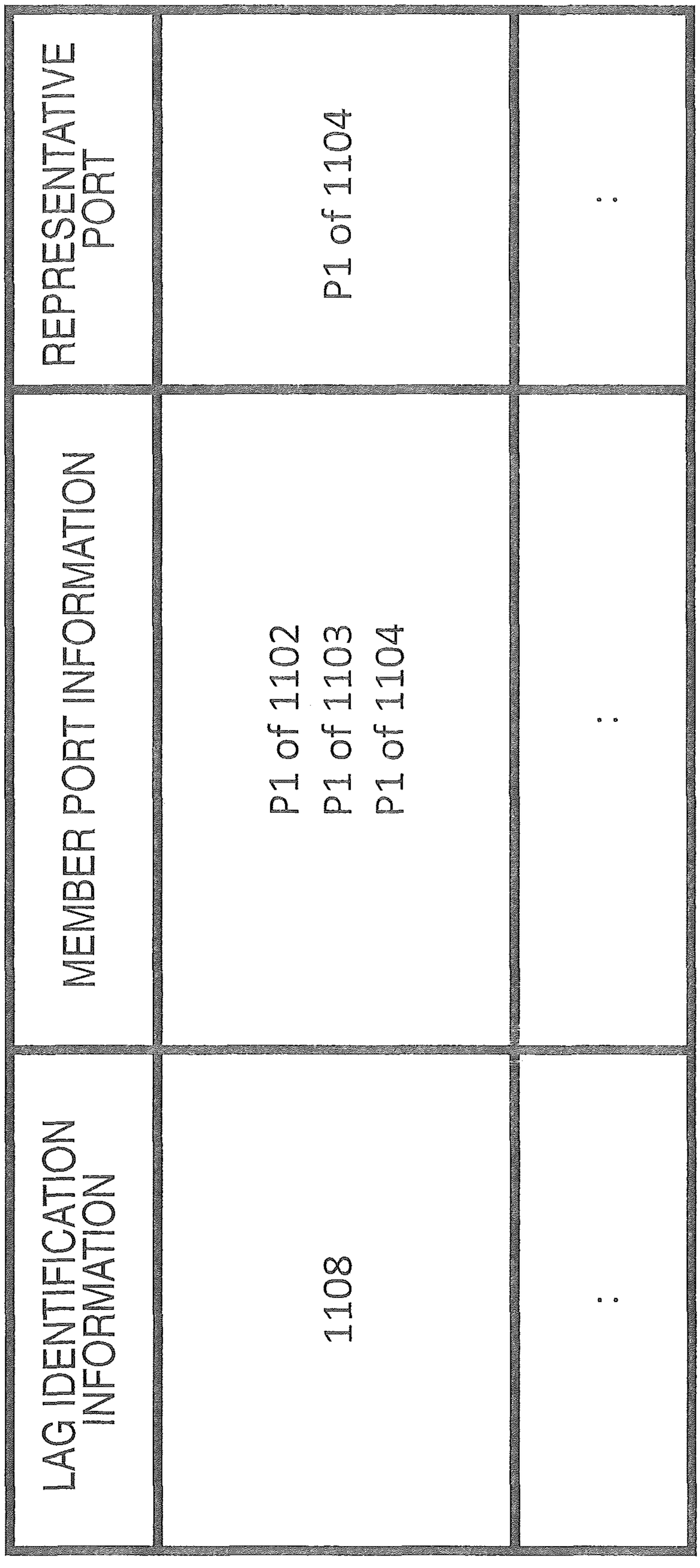

REPRESENTATIVE PORT
P1 of 1104
..
MEMBER PORT INFORMATION
P1 of 1102
P1 of 1103
P1 of 1104
..
LAG IDENTIFICATION INFORMATION
1108
..

FIG. 6

FIG. 7

LAG IDENTIFICATION INFORMATION	TERMINAL INFORMATION
1108	MAC of 1101
:	:

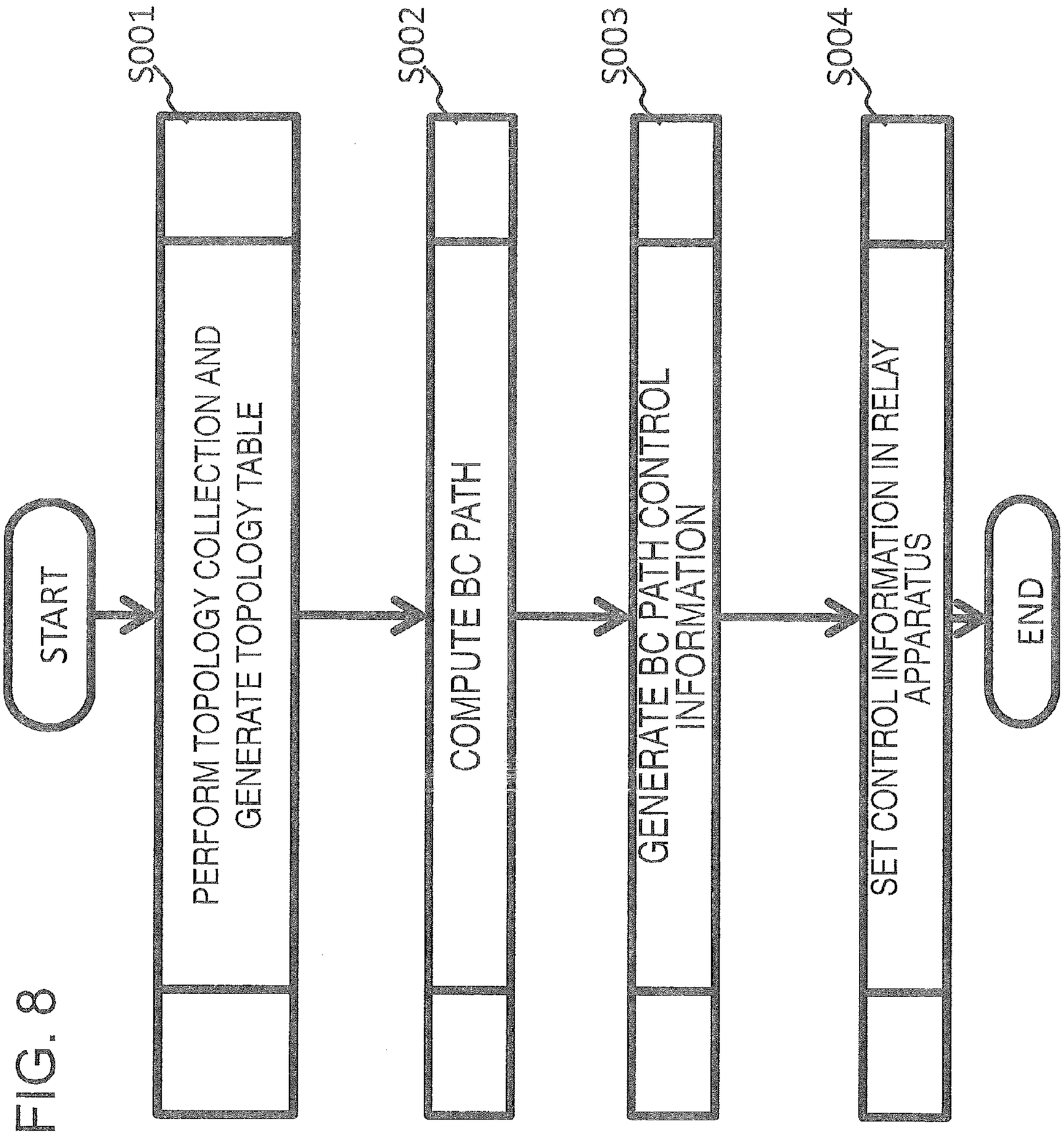

START
S001
PERFORM TOPOLOGY COLLECTION AND GENERATE TOPOLOGY TABLE
S002
COMPUTE BC PATH
S003
GENERATE BC PATH CONTROL INFORMATION
S004
SET CONTROL INFORMATION IN RELAY APPARATUS
END

FIG. 8

RELAY APPARATUS	PORT	MATCH CONDITION	INSTRUCTIONS
1102	P1	BC PACKET	FORWARD TO P3 AND P4
1102	P4	BC PACKET	FORWARD TO P1 AND P3
1102	P3	ANY (WILD CARD)	FORWARD TO P4
1103	P1	BC PACKET	FORWARD TO P2 AND P3
1103	P2	ANY (WILD CARD)	FORWARD TO P1 AND P3
1103	P3	ANY (WILD CARD)	FORWARD TO P1 AND P2
1104	P1	BC PACKET	FORWARD TO P3 AND P4
1104	P3	ANY (WILD CARD)	FORWARD TO P1 AND P4
1104	P4	BC PACKET	FORWARD TO P1 AND P3

FIG. 9

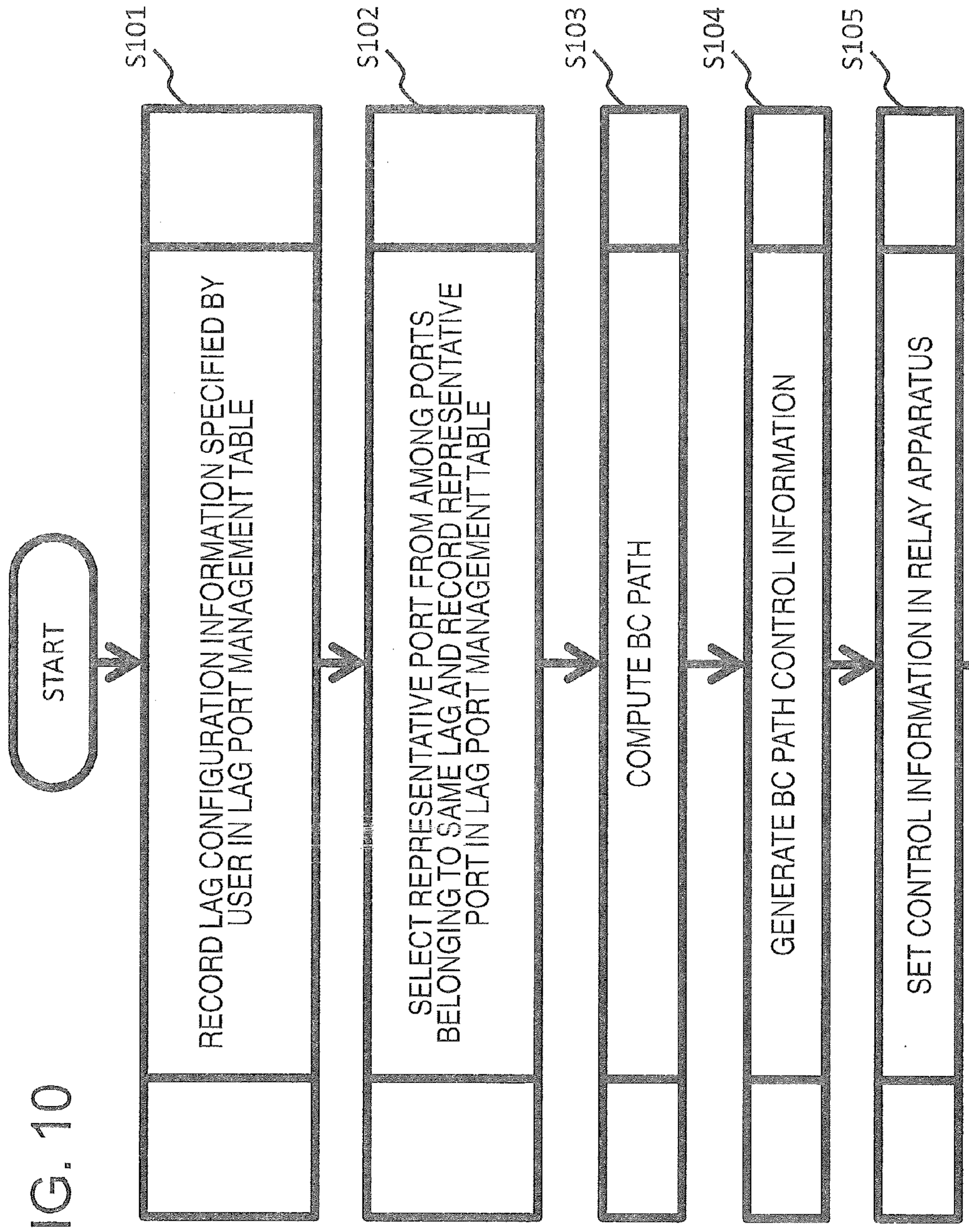

S101
S102
S103
S104
S105
START
RECORD LAG CONFIGURATION INFORMATION SPECIFIED BY USER IN LAG PORT MANAGEMENT TABLE
SELECT REPRESENTATIVE PORT FROM AMONG PORTS BELONGING TO SAME LAG AND RECORD REPRESENTATIVE PORT IN LAG PORT MANAGEMENT TABLE
COMPUTE BC PATH
GENERATE BC PATH CONTROL INFORMATION
SET CONTROL INFORMATION IN RELAY APPARATUS
END

FIG. 10

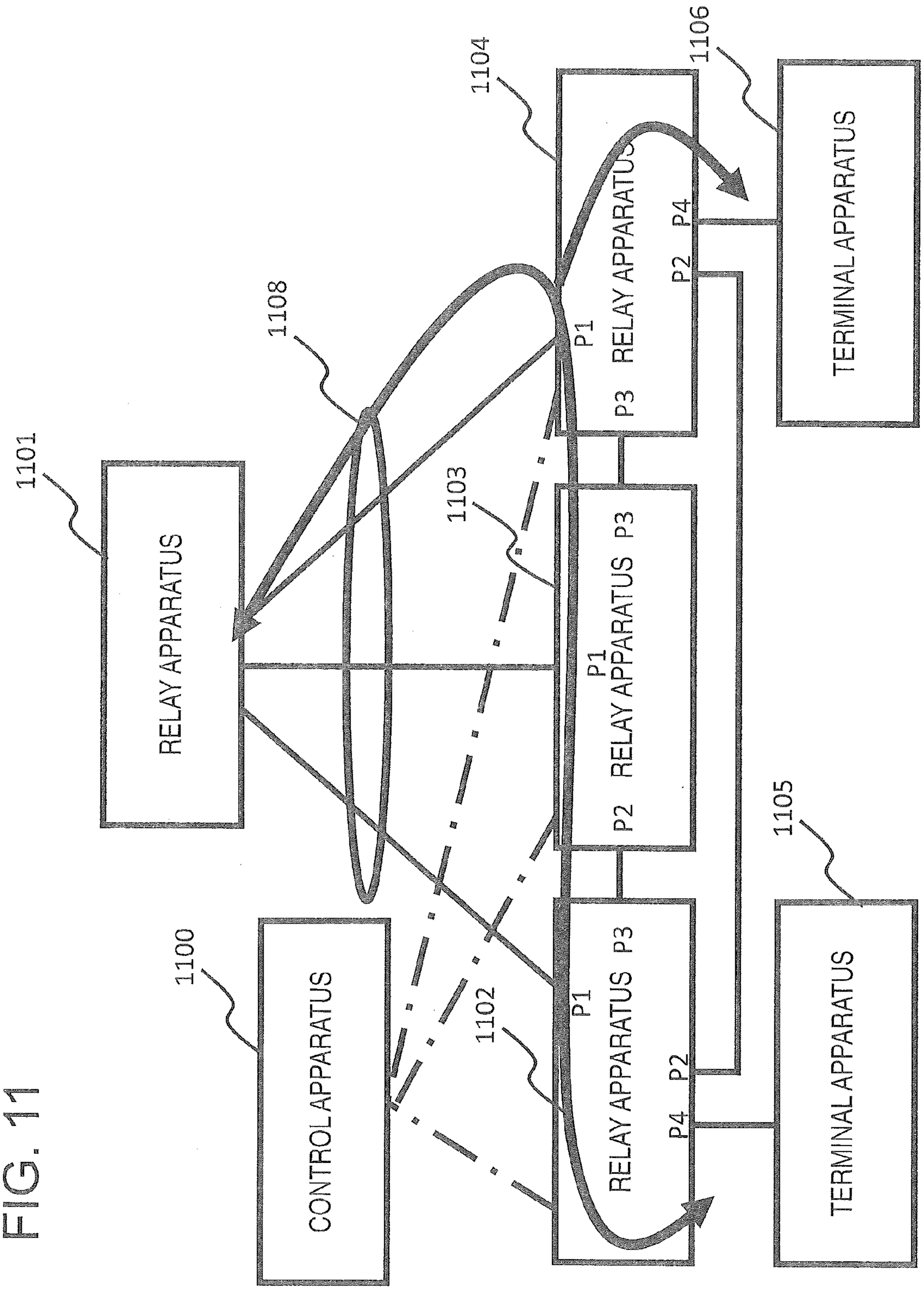

1104
1106
1108
1101
1103
1105
1100
1102
RELAY APPARATUS
CONTROL APPARATUS
TERMINAL APPARATUS
P1
P2
P3
P4

FIG. 11

RELAY APPARATUS	PORT	MATCH CONDITION	INSTRUCTIONS
1102	P1	BC PACKET	FORWARD TO CONTROL APPARATUS
1102	P4	BC PACKET	FORWARD TO P3
1102	P3	ANY (WILD CARD)	FORWARD TO P4
1103	P1	BC PACKET	FORWARD TO CONTROL APPARATUS
1103	P2	ANY (WILD CARD)	FORWARD TO P3
1103	P3	ANY (WILD CARD)	FORWARD TO P2
1104	P1	BC PACKET	FORWARD TO CONTROL APPARATUS
1104	P3	ANY (WILD CARD)	FORWARD TO P1 AND P4
1104	P4	BC PACKET	FORWARD TO P1 AND P3

FIG. 12

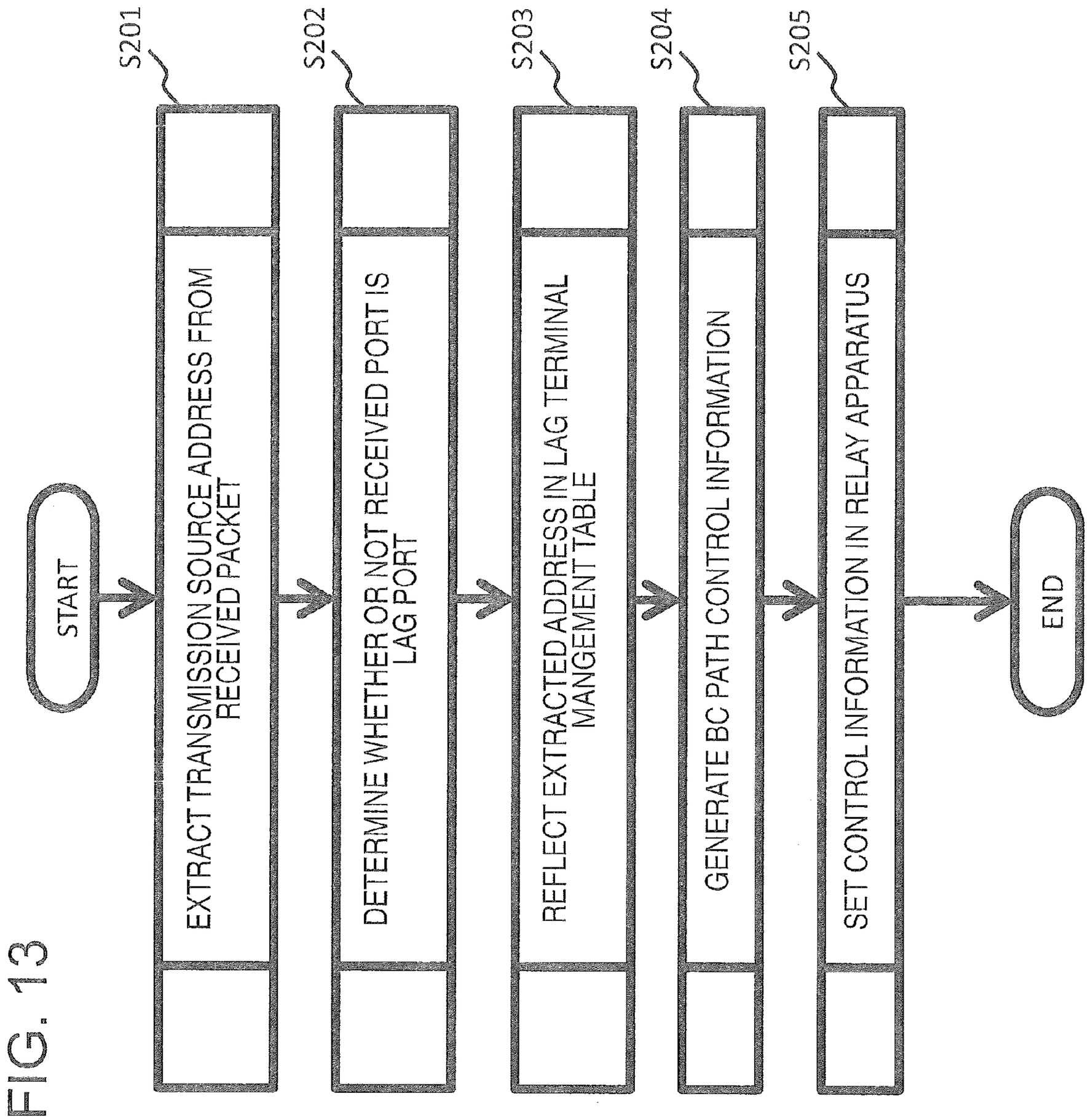

START
S201
EXTRACT TRANSMISSION SOURCE ADDRESS FROM RECEIVED PACKET
S202
DETERMINE WHETHER OR NOT RECEIVED PORT IS LAG PORT
S203
REFLECT EXTRACTED ADDRESS IN LAG TERMINAL MANGEMENT TABLE
S204
GENERATE BC PATH CONTROL INFORMATION
S205
SET CONTROL INFORMATION IN RELAY APPARATUS
END

FIG. 13

RELAY APPARATUS	PORT	MATCH CONDITION	INSTRUCTIONS
1102	P3	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P4
1103	P2	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P3
1103	P3	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P2
1104	P3	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P4

FIG. 14

RELAY APPARATUS	PORT	MATCH CONDITION	INSTRUCTIONS
1102	P1	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P3 AND P4
1103	P1	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P2 AND P3
1104	P1	TRANSMISSION SOURCE MAC IS 1101 AND BC PACKET	FORWARD TO P3 AND P4

FIG. 15

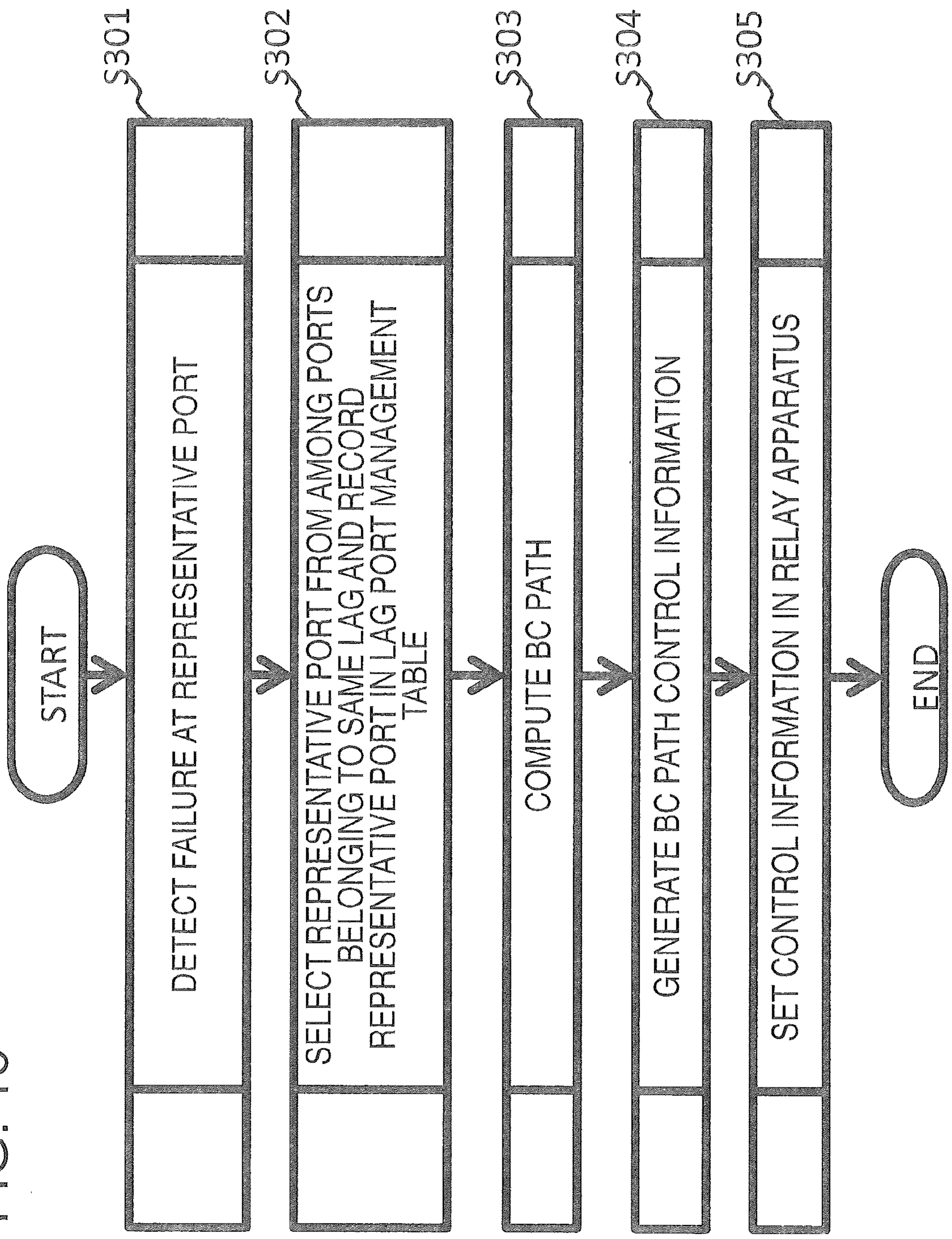

START
S301
DETECT FAILURE AT REPRESENTATIVE PORT
S302
SELECT REPRESENTATIVE PORT FROM AMONG PORTS BELONGING TO SAME LAG AND RECORD REPRESENTATIVE PORT IN LAG PORT MANAGEMENT TABLE
S303
COMPUTE BC PATH
S304
GENERATE BC PATH CONTROL INFORMATION
S305
SET CONTROL INFORMATION IN RELAY APPARATUS
END

FIG. 16

CONTROL APPARATUS, COMMUNICATION SYSTEM, COMMUNICATION METHOD, AND PROGRAM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is based upon and claims the benefit of the priority of Japanese Patent Application No. 2012-026813 (filed on Feb. 10, 2012), the disclosure of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

The present invention relates to a control apparatus, a communication system, a communication method, and a program. More specifically, the invention relates to a control apparatus configured to perform centralized control over a relay apparatus, a communication system including the control apparatus, a communication method, and a program.

BACKGROUND

In recent years, the technology called OpenFlow (OpenFlow) is proposed (refer to Non Patent Literatures 1 and 2). OpenFlow identifies communications as end-to-end flows, and performs path control, failure recovery, load distribution, and optimization on a per-flow basis. An OpenFlow switch specified in Non Patent Literature 2 includes a secure channel for communication with an OpenFlow controller. The OpenFlow switch operates according to a flow table in which appropriate adding or rewriting is instructed by the OpenFlow controller. In the flow table, a set of a matching condition (Match condition) to be matched against a packet header, flow statistics information (Counters), and instructions (Instructions) defining processing content is defined for each flow (refer to section "4.1 Flow Table" in Non Patent Literature 2).

When the OpenFlow switch receives a packet, for example, the OpenFlow switch searches the flow table for an entry having a matching condition that matches header information of the received packet (refer to "4.3 Match Fields" in Non Patent Literature 2). When the entry that matches the received packet is found as a result of the search, the OpenFlow switch updates the flow statistics information (one or more Counters), and executes processing content (e.g., transmission of the packet from a specified port, flooding of the packet, discarding of the packet, or the like) described in the instruction field of the entry. On the other hand, when the entry that matches the received packet is not found as a result of the search, the OpenFlow switch transmits to the OpenFlow controller a request for setting the entry, or a request for determining the processing content of the received packet, through the secure channel. The OpenFlow switch receives the flow entry in which the processing content is defined, and then updates the flow table. In this manner, the OpenFlow switch performs packet forwarding by using the entry stored in the flow table as a processing rule.

Patent Literature 1 discloses an invention in which physical ports belonging to a link aggregation group are also to be managed by an OpenFlow controller. A user can thereby be made to arbitrarily control the physical port of an output destination, without depending on a sorting algorithm or the like inside an apparatus including the physical ports belonging to the link aggregation group.

Patent Literature 1:
JP Patent Kokai Publication No. JP2011-160171A

Non-Patent Literature 1:
Nick McKeown and seven other authors, "OpenFlow: Enabling Innovation in Campus Networks," [online], [Searched on Jan. 11, 2012], Internet <URL: http://www.openflow.org/documents/openflow-wp-latest.pdf>.

Non-Patent Literature 2
"*OpenFlow Switch Specification,*" Version 1.1.0 Implemented (Wire Protocol 0x02), [online][Searched on Jan. 11, 2012], Internet <URL:http://www.openflow.org/documents/openflow-spec-v1.1.0.pdf>.

SUMMARY

Each disclosure of the related art literatures is incorporated herein by reference.

The following analysis is given by the present invention. In a configuration where a link aggregation group is set on an OpenFlow network as in Patent Literature 1, however, there is a problem that, when a broadcast packet or a multicast packet flows into the OpenFlow network, the same packet is duplicately forwarded, depending on the behavior of a node at each end of the link aggregation group, so that traffic distribution cannot be performed according to a rule set for the link aggregation group.

Therefore, there is a need in the art to efficiently forwarding a broadcast packet and a multicast packet even in an environment where a link aggregation group is set on a network of a centralized control type represented by OpenFlow.

According to a first aspect, there is provided a control apparatus, comprising: a topology management unit that manages a network topology formed by including a plurality of relay apparatuses; a link aggregation group management unit that groups ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and manages the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node; and a relay apparatus control unit that controls the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link.

According to a second aspect, there is provided a communication system that comprises: the above control apparatus; and a relay apparatus that is controlled by the control apparatus.

According to a third aspect, there is provided a communication method by a control apparatus comprising a topology management unit that manages a network topology formed by including a plurality of relay apparatuses, the communication method comprising: grouping ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and managing the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node; and controlling the plurality of relay apparatuses, having the grouped ports, so that when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link.

According to a fourth aspect, there is provided a program for a computer constituting a control apparatus comprising a topology management unit that manages a network topology formed by including a plurality of relay apparatuses, the program causing the computer to execute: grouping ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and storing the

grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node; and controlling the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link.

The present invention provides the following advantage, but not restricted thereto. According to the present invention, even under an environment where a link aggregation group has been set on the network of a centralized control type represented by OpenFlow, a broadcast packet and a multicast packet can be efficiently forwarded.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram showing an example of a configuration of an exemplary embodiment of the present invention.

FIG. **2** is a diagram for explaining an example of an operation of the exemplary embodiment of the present invention.

FIG. **3** is a diagram showing an example of a configuration of a first exemplary embodiment of the present invention.

FIG. **4** is a block diagram showing an example of a detailed configuration of a control apparatus in the first exemplary embodiment of the present invention.

FIG. **5** is a table showing an example of a topology table held in the control apparatus in the first exemplary embodiment of the present invention.

FIG. **6** is a table showing an example of a LAG port management table held in the control apparatus in the first exemplary embodiment of the present invention.

FIG. **7** is a table showing an example of a LAG terminal management table held in the control apparatus in the first exemplary embodiment of the present invention.

FIG. **8** is a flowchart showing an example of an operation (before registration of a LAG) in the first exemplary embodiment of the present invention.

FIG. **9** shows an example of control information set in each relay apparatus (before LAG port formation) in the first exemplary embodiment of the present invention.

FIG. **10** is a flowchart showing an example of an operation (of a LAG registration reception and path recomputation) in the first exemplary embodiment of the present invention.

FIG. **11** is a diagram showing an example of computation of a broadcast path that passes through a representative port.

FIG. **12** shows an example of control information set in each relay apparatus (after the LAG registration reception and the path recomputation) in the first exemplary embodiment of the present invention.

FIG. **13** is a flowchart showing an example of an operation (of setting LAG port control information) in the first exemplary embodiment of the present invention.

FIG. **14** shows an example of control information set in each relay apparatus (for preventing forwarding to any LAG port) in the first exemplary embodiment of the present invention.

FIG. **15** shows an example of control information set in each relay apparatus (when receiving from one of LAG ports) in the first exemplary embodiment of the present invention.

FIG. **16** is a flowchart showing an example of an operation (of resetting control information when a LAG port failure has occurred) in the first exemplary embodiment of the present invention.

PREFERRED MODES

In the present disclosure, there are various possible modes, which include the following, but not restricted thereto. First, an overview of an exemplary embodiment of the present invention will be described with reference to the drawings. In the following description, a reference sign in each drawing appended to this overview is appended to each element for convenience, as an example for help understanding, and does not intend to limit the present invention to the mode that has been illustrated.

As shown in FIG. **1**, the exemplary embodiment of the present invention can be implemented by a plurality of relay apparatuses **1102** to **1104** configured to relay a packet between terminal apparatuses **1101**, **1105**, and **1106** and a control apparatus **1100**A configured to control these relay apparatuses **1102** to **1104**.

More specifically, the control apparatus **1100**A comprises a topology management unit **101** that manage a network topology formed by including a plurality of relay apparatuses **1102** to **1104**; a link aggregation group management unit (LAG management unit) **102** that groups ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and manages the grouped ports as a virtual logical link between the plurality of the relay apparatuses and the arbitrary node; and a relay apparatus control unit **103** that controls the plurality of relay apparatuses. The relay apparatus control unit **103** controls the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link.

Assume that a link aggregation group (LAG) is formed by grouping ports of the relay apparatuses **1102** to **1104** connected to the terminal apparatus **1101** through physical links L**1** to L**3** as shown in FIG. **2**, for example. Then, the relay apparatus control unit **103** controls the plurality of relay apparatuses, each having a port among the grouped ports, so that, when one of the relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to a plurality of the physical links that form the virtual logical link.

More specifically, the relay apparatus control unit **103** controls the relay apparatuses **1101** to **1103** so that the broadcast packet or the multicast packet is forwarded along a path including a predetermined representative one of the ports (link L**3** using the representative port as an end point) and does not pass through the ports (end points of the links L**1** and L**2**), which are not the representative port, as shown in arrowed lines in FIG. **2**.

With the above-mentioned arrangement, the broadcast packet and the multicast packet can be efficiently forwarded even under an environment where the link aggregation group has been set.

[First Exemplary Embodiment]

Next, a first exemplary embodiment of the present invention will be described in detail with reference to the drawings. FIG. **3** is a diagram showing an example of a configuration of the first exemplary embodiment of the present invention. Referring to FIG. **3**, the configuration including terminal apparatuses **1101**, **1105**, and **1106**, relay apparatuses **1102**, **1103**, and **1104**, and a control apparatus **1100** is shown. The terminal apparatuses **1101**, **1105**, and **1106** are configured to perform mutual communication through a network. The relay apparatuses **1102**, **1103**, and **1104** are each configured to forward a packet transmitted from each of the terminal apparatuses as a communication path between the respective terminal apparatuses **1101**, **1105**, and **1106**. The control apparatus **1100** is configured to be connected to each of the relay apparatuses **1102**, **1103**, and **1104** through a control channel

(indicated by a dashed line in FIG. **3**) and controls the relay devices **1102**, **1103**, and **1104**. A reference sign **1108** in FIG. **3** represents a link aggregation group.

The relay apparatuses **1102**, **1103**, and **1104** can be formed by an OpenFlow switch described in each of Non-Patent Documents 1 and 2, for example. Another switching apparatus capable of forwarding a packet based on control information from the control apparatus **1100** can also be used. Each of reference signs P**1** to P**4** shown within boxes indicating the relay apparatuses **1102**, **1103**, and **1104** indicates a port number of each relay apparatus.

The terminal apparatuses **1101**, **1105**, and **1106** are a computer to be operated by a user of the network, a server configured to provide a service and content to these computers, or the like.

FIG. **4** is a block diagram showing a detailed configuration of the control apparatus in the first exemplary embodiment of the present invention. Referring to FIG. **4**, the configuration is shown which includes a relay apparatus communication unit **111**, a topology generation unit **112**, a topology table **113**, a broadcast path computation unit (BC path computation unit) **114**, a broadcast path control unit (BC path control unit) **115**, an address acquisition unit **116**, a link aggregation group management unit (LAG management unit) **117**, a link aggregation group port management table (LAG port management table) **118**, and a link aggregation group terminal management table (LAG terminal management table) **119**.

The relay apparatus communication unit **111** transmits a control command to each of the relay apparatuses **1102** to **1104** in response to a request from the topology generation unit **112** or the BC path control unit **115**. The relay apparatus communication unit **111** forwards a response from each of the relay apparatuses **1102** to **1104** to the topology generation unit **112** and the BC path control unit **115**.

The topology generation unit **112** requests connection information of each relay apparatus to each of the relay apparatuses **1102** to **1104** through the relay apparatus communication unit **111**, generates a network topology based on a result of response of each of the relay apparatuses **1102** to **1104**, and then records the generated network topology in the topology table **113**. As a collection method of the connection information, a method may be pointed out where a specific one of the relay apparatuses is made to transmit a packet for arrival confirmation to all ports, a result of receiving the packet for arrival confirmation is stored in each relay apparatus, and then the control apparatus **1100** reads the connection information between the respective relay apparatuses, based on the stored result of receiving the packet. Alternatively, a method may be employed where receipt of the packet for arrival confirmation is notified to the control apparatus **1100** by each relay apparatus without storing the result of receiving the packet for arrival confirmation in the relay apparatus. As a typical protocol of this type, there is an LLDP (Link Layer Discovery Protocol). However, other protocols may be employed. Alternatively, a method may be used where the topology generation unit **112** receives an input of topology information from the user and registers the topology information in the topology table **113**.

FIG. **5** shows an example of the topology table corresponding to the network configuration in FIG. **3**. Referring to FIG. **3**, the port P**1** of the relay apparatus **1102** is connected to the terminal apparatus **1101**. Thus, referring to FIG. **5**, an adjacent relay apparatus of the relay apparatus **1102** and information on an adjacent port of the relay apparatus **1102** are both "None." On the other hand, the port P**2** of the relay apparatus **1102** is connected to the relay apparatus **1104**. Thus, referring to FIG. **5**, the adjacent relay apparatus of **1104** and the adjacent port information of P**2** (indicating that the relay apparatus **1102** is opposed to the port P**2** of the adjacent relay apparatus **1104**) are obtained.

The BC path computation unit **114** computes a broadcast path starting from each of the terminal apparatuses **1101**, **1105**, and **1106**, by referring to the network topology registered in the topology table **113**. As a computation method of the broadcast path, a minimum spanning tree (of which a Prim's algorithm and a Kruskal's algorithm are representative) or the like may be employed.

The BC path control unit **115** corresponds to the relay apparatus control unit **103** in FIG. **1** mentioned above, generates control information for executing a packet forwarding along the broadcast path computed by the BC path computation unit **114**, and sets the control information in the relay apparatuses **1102** to **1104** through the relay apparatus communication unit **111**. Even when the LAG port management table **118** or the LAG terminal management table **119** is updated, the BC path control unit **115** performs control information resetting in view of the presence of the LAG and the representative port of the LAG, according to the procedure that will be described later.

Though omitted in the description of this exemplary embodiment, the BC path computation unit **114** and the BC path control unit **115** may compute a unicast path and may set control information for unicast in response to a request from each of the relay apparatuses **1102** to **1104** through the relay apparatus communication unit **111**.

The address acquisition unit **116** extracts the transmission source address and the transmission destination address of the packet from the relay apparatus communication unit **111**, and then outputs the extracted transmission source and destination addresses to the LAG management unit **117**.

The LAG management unit **117** manages information for identifying the link aggregation group (hereinafter referred to as "LAG identification information") and each terminal apparatus connected to the link aggregation group, using the LAG port management table **118** and the LAG terminal management table **119**. The LAG management unit **117** selects, from among the ports of the relay apparatuses of the LAG to which the LAG identification information has been given (hereinafter referred to as "member ports"), one port representative of the member ports (hereinafter referred to as the "representative port"). The representative port may be selected, using an appropriate algorithm in view of equalization of traffic at each member port and a link cost.

The LAG port management table **118** is a table for managing the configuration, which indicates LAG port information and so forth. FIG. **6** shows an example of the LAG port management table **118**. In the example in FIG. **6**, the LAG using, as the member ports, the ports (ports P**1** of the relay apparatuses **1102** to **1104**) of the relay apparatuses (e.g., the relay apparatuses **1102** to **1104** in FIG. **3**) connected to a certain one of the terminal apparatuses (e.g., the terminal apparatus **1101** in FIG. **3**) is registered. The port P**1** of the relay apparatus **1104** is selected as the representative port of this LAG.

The LAG terminal management table **119** is a table for managing each terminal connected to the LAG. FIG. **7** shows an example of the LAG terminal management table **119**. In the example in FIG. **7**, the MAC (Media Access Control) address of the terminal apparatus **1101** is associated with the LAG identification information of "**1108**" described above. This corresponds to a state where the terminal apparatus **1101** is connected to the LAG **1108**.

Each unit (processing means) of the control apparatus **1100** shown in FIG. **4** can also be implemented by a computer

program that causes a computer which constitutes the control apparatus **1100** to execute each of processes described above, using hardware of the computer.

Next, an example of an operation of this exemplary embodiment will be described in detail with reference to the drawings. First, generation of the network topology and setting of the broadcast path by the control apparatus **1100** (before registration of the LAG) will be described.

FIG. **8** is a flowchart showing an example of an operation of the first exemplary embodiment (before registration of the LAG). Referring to FIG. **8**, the topology generation unit **112** first collects the connection information between the respective relay apparatuses through the relay apparatus communication unit **111**, thereby generating the network topology (in step S**001**). The topology generation unit **112** records the generated topology in the topology table **113**.

Next, the BC path computation unit **114** computes the broadcast path, by referring to the topology table **113** (in step S**002**).

Next, the BC path control unit **115** generates the control information for each of the relay apparatuses **1102** to **1104**, according to a result of computation of the broadcast path by the BC path computation unit **114** (in step S**003**). It is assumed in this exemplary embodiment that a flow entry which associates match fields (Match Fields) to be checked against a received packet and instructions (Instructions) configured to define processing content is generated, as the control information.

Next, the BC path control unit **115** requests transmission of the generated control information to the relay apparatus communication unit **111**. The relay apparatus communication unit **111** that has received the request sets the control information in the relay apparatuses (in step S**004**). In this case, the BC path control unit **115** may set in each relay apparatus the control information for causing a specific one of broadcast packets to be forwarded to the control apparatus **1100**. As the specific one of the broadcast packets, an ARP (Address Resolution Protocol) packet, or an LACP (Link Aggregation Control Protocol) packet, for example, may be pointed out. This allows recognition of each terminal apparatus and execution of a negotiation with respect to link aggregation.

FIG. **9** shows an example of the control information generated by the BC path control unit **115**. The first to third ones of the control information from the top of FIG. **9** are set in the relay apparatus **1102**. Similarly, the fourth to sixth ones of the control information from the top of FIG. **9** are set in the relay apparatus **1103**, and the seventh to ninth ones of the control information from the top of FIG. **9** are set in the relay apparatus **1104**. When the relay apparatus **1102** receives a broadcast packet (hereinafter referred to as a "BC" packet) at the port P**1**, for example, the relay apparatus **1102** confirms that the BC packet matches a Match condition (being a BC packet), and forwards the BC packet to the ports P**3** and P**4**. The BC packet transmitted from the port P**4** of the relay apparatus **1102** arrives at the terminal apparatus **1105**. On the other hand, the BC packet transmitted from the port P**3** of the relay apparatus **1102** is received at the port P**2** of the relay apparatus **1103**. When the relay apparatus **1103** receives the broadcast packet (hereinafter referred to the "BC packet") at the port P**2**, the relay apparatus **1103** confirms that the BC packet matches a Match condition (being Any (not specified)), and forwards the BC packet to the ports P**1** and P**3**. Hereinafter, similarly, the BC packet arrives at every node.

Next, an operation of resetting (optimizing) control information after the link aggregation has been registered by the user will be described.

FIG. **10** is a flowchart showing an example of an operation (of receiving registration of the LAG and recomputing a path) in the first exemplary embodiment. Referring to FIG. **10**, the LAG management unit **117** first records in the LAG port management table **118** LAG configuration information (formed of the LAG identification information and member port information) specified by the user (in step S**101**). It is herein assumed that the LAG configuration information formed of the LAG identification information of **1108** and the member port information of P**1** of (the relay apparatus) **1102**, P**1** of (the relay apparatus) **1103**, and P**1** of (the relay apparatus) **1104** are recorded, as shown in FIG. **6**.

Next, the LAG management unit **117** selects the representative port from the ports belonging to the same LAG, and records the representative port in the LAG port management table **118** in step S**102**). It is assumed herein that the port P**1** of (the relay apparatus) **1104** has been selected as the representative port.

Next, the BC path computation unit **114** computes a broadcast path, by referring to the topology table **113** and the LAG port management table **118** (in step S**103**). FIG. **11** is a diagram showing the broadcast path so computed as to pass through the selected representative port.

Next, the BC path control unit **115** generates the control information for implementing packet forwarding along the computed broadcast path (in step S**104**). In this case, the BC path control unit **115** excludes the ports other than the representative port of the ports (member ports) belonging to the same LAG from a distribution destination.

Finally, the BC path control unit **115** requests the relay apparatus communication unit **111** to transmit the generated control information. The relay apparatus communication unit **111** that has received the request sets the control information in the relay apparatuses (in step S**105**).

FIG. **12** shows an example of the control information generated by the BC path control unit **115**. The control information in FIG. **12** is different from the control information shown in FIG. **9** in that when a BC packet is received at the member port P**1**, the packet is forwarded to the control apparatus **1100** and that the ports P**1** are deleted from the port of the forwarding destination (refer to broken-line circles in FIG. **12**), which is associated with the broadcast path in FIG. **11**. Setting of these control information can also be implemented by requesting rewriting of Instructions Fields of these control information when the control information shown in FIG. **9** has already been set in each of the relay apparatuses **1102** to **1104**.

In the example in FIG. **12**, when the relay apparatus **1104** receives a BC packet at the port P**4**, the relay apparatus **1102** confirms that the BC packet matches a Match condition (being a BC packet), and then forwards the BC packet to the port P**1** and the port P**3**. The BC packet transmitted from the port P**1** of the relay apparatus **1104** arrives at the terminal apparatus **1101**. On the other hand, the BC packet transmitted from the port P**3** of the relay apparatus **1104** is received at the port P**3** of the relay apparatus **1103**. When the relay apparatus **1103** receives the broadcast packet (hereinafter referred to as the "BC packet") at the port P**3**, the relay apparatus **1103** confirms that the BC packet matches a Match condition (being Any (not specified)), and forwards the BC packet to the port P**2**. Hereinafter, similarly, the BC packet arrives at every node.

Next, a description will be given about an operation when a BC packet is transmitted from the terminal apparatus **1101** connected to the LAG in a state where the control information as mentioned above has been set.

When the BC packet is transmitted from the terminal apparatus **1101**, the BC packet is received at one of the member ports P**1** of the relay apparatuses **1102** to **1104** that form the LAG. The BC packet is then forwarded to the control apparatus **1100** as shown in the control information in FIG. **12** described above.

FIG. **13** is a flowchart showing an example of an operation of the control apparatus **1100** (of setting LAG port control information) when a BC packet is received from the terminal apparatus **1101** connected to the above-mentioned LAG. Referring to FIG. **13**, when the control apparatus **1100** receives the BC packet, the address acquisition unit **116** obtains transmission source address information from the received BC packet, and notifies the transmission source address information to the LAG management unit **117** together with information on the relay apparatus and the port of the relay apparatus for the transmission source of the BC packet (in step S**201**). It is assumed herein that the address information of the terminal apparatus **1101** in FIG. **3** is obtained.

Next, the LAG management unit **117** checks whether or not the BC packet has been received at the port belonging to the LAG, by referring to the LAG port management table **118** (in step S**202**). Herein, when the BC packet is not received at the port belonging to the LAG, subsequent processes are omitted.

Next, the LAG management unit **117** associates and registers in the LAG terminal management table **119** the LAG identification information with the address of the transmission source notified from the address acquisition unit **116** (in step S**203**).

Further, the LAG management unit **117** requests the BC path control unit **115** to generate the control information for processing the BC packet from the terminal apparatus connected to the LAG (in step S**204**). The BC path control unit **115** that has received the request additionally generates the following two types of the control information.

A first one of the control information is control information (hereinafter referred to as "transmission source filtering BC") configured not to forward to the representative port of the LAG a packet with the address of the terminal apparatus (terminal apparatus **1101**, herein) connected to the LAG port as transfer source information, when the packet is received at the port of the relay apparatus to which the representative port of the same LAG belongs.

FIG. **14** shows an example of the control information (transmission source filtering BC) to be generated by the BC path control unit **115**. A difference from the control information for the same port of a same one of the relay apparatuses shown in FIG. **12** is that, as each Match condition, the MAC address of the relay apparatus **1101** (that can be obtained from the LAG terminal management table **119**) is set, and that the port P**1** is excluded from a forwarding destination. With this arrangement, a BC packet transmitted from the terminal apparatus **1101** is not forwarded to any one of the member ports, thereby avoiding a loop.

A second one of the control information is control information (hereinafter referred to as "transmission source permitting BC") configured to cause packet forwarding to be performed along the broadcast path when a BC packet using the MAC address of the terminal apparatus **1101** connected to the LAG as a transfer source is received at one of the member ports of the LAG.

FIG. **15** shows an example of the control information (transmission source permitting BC) generated by the BC path control unit **115**. With this arrangement, a BC packet from the terminal apparatus **1101** connected to the LAG is forwarded to a different one of the relay apparatuses or a different one of the terminal apparatuses.

A higher priority than the control information shown in FIG. **12** is given to each of the first control information in FIG. **14** and the second control information in FIG. **15**. As a method of giving the priority, priority information may be given to each control information, or storage positions of the first control information and the second control information may be instructed so that the first control information and the second control information are searched at each relay apparatus earlier than the control information shown in FIG. **12**.

Finally, the BC path control unit **115** requests the relay apparatus communication unit **111** to transmit the generated first and second control information (transmission source filtering BC and transmission source permitting BC). The relay apparatus communication unit **111** that has received the request sets the control information in the relay apparatuses (in step S**205**).

By setting the first and second control information as described above, when each relay apparatus receives a BC packet, each relay apparatus can be controlled not to flow the same BC packet into links that form the LAG.

According to the configuration of this exemplary embodiment, the same control can be continued even if a failure has occurred at the representative port of a LAG. A detailed description will be given below about operations when the failure has occurred at the representative port of the LAG, with reference to the drawing.

FIG. **16** is a flowchart showing an example of an operation of the control apparatus **1100** (of resetting control information when the failure has occurred at the LAG port) when the failure has occurred at the representative port of the LAG. Referring to FIG. **16**, the LAG management unit **117** detects the failure at the representative port (in step S**301**). The failure of the representative port can be detected by collection of the connection information between the respective relay apparatuses by the topology generation unit **112**, notification from each terminal apparatus, or the like, for example.

Next, the LAG management unit **117** refers to the LAG port management table, selects a representative port from the member ports of the LAG where the failure has occurred at the representative port, and records the representative port in the LAG port management table **118** (in step S**302**).

Since the subsequent operations are the same as the content described with reference to FIG. **10** (in steps S**303** to S**305**). In this case as well, the procedure shown in FIG. **13** is performed to set first control information and second control information (transmission source filtering BC and transmission source permitting BC), if needed. As described above, the present invention achieves effects as will be described below.

As described above, according to this exemplary embodiment, even under an environment where a LAG has been set on a network of a centralized control type represented by OpenFlow, a BC packet can be efficiently forwarded. Further, traffic between a terminal apparatus and relay apparatuses connected to the LAG can also be finely distributed, using the above-mentioned algorithm of selecting a representative port.

Though the above description was directed to the exemplary embodiment of the present invention, the present invention is not limited to the above-mentioned exemplary embodiment. Further variation, substitution, and adjustment can be added within the scope not departing from the basic technical concept of the present invention. To take an example, the description of the above-mentioned exemplary embodiment

was given, assuming that a broadcast packet is to be handled. The present invention, however, can be similarly applied to a multicast packet as well.

The numbers of the control apparatus, the terminal apparatuses, and the relay apparatuses and the configuration of the network illustrated in the above-mentioned exemplary embodiment are an example shown to help understanding of the present invention. No particular limitation is imposed on the present invention. The present invention can also be applied to a different network configuration capable of forming a LAG.

Each disclosure of the above-listed Patent Literature and Non Patent Literatures is incorporated herein by reference. Modification and adjustment of each exemplary embodiment and each example are possible within the scope of the overall disclosure (including the claims) of the present invention and based on the basic technical concept of the present invention. Various combinations and selections of various disclosed elements (including each element in each claim, each element in each exemplary embodiment and each example, each element in each drawing, and the like) are possible within the scope of the claims of the present invention. That is, the present invention naturally includes various variations and modifications that could be made by those skilled in the art according to the overall disclosure including the claims and the technical concept.

P**1**-P**4** port (number)
101 topology management unit
102, **117** link aggregation group management unit (LAG management unit)
103 relay apparatus control unit
111 relay apparatus communication unit
112 topology generation unit
113 topology table
114 broadcast path computation unit (BC path computation unit)
115 broadcast path control unit (BC path control unit)
116 address acquisition unit
118 link aggregation group port management table (LAG port management table)
119 link aggregation group terminal management table (LAG terminal management table)
1101, **1105**, **1106** terminal apparatus
1102, **1103**, **1104** relay apparatus
1100, **1100**A control apparatus

What is claimed is:

1. A control apparatus, comprising:
a memory storing instructions; and
a processor that executes the instructions to:
manage a network topology formed by including a plurality of relay apparatuses;
group ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology;
manage the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;
control the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link; and
manage a node connected through the virtual logical link to the plurality of relay apparatuses, having the grouped ports;
wherein depending on whether or not a transfer source of a packet is the managed node, the packet is determined to be a broadcast packet to be controlled or a multicast packet to be controlled;
wherein the processor further executes the instructions to, when one of the plurality of relay apparatuses, having the grouped port, receiving a broadcast packet or a multicast packet from the port after the virtual logical link has been set, set in the relay apparatus control information that causes the relay apparatus to forward the broadband packet or the multicast packet to the control apparatus;
wherein the processor further executes the instructions to, upon reception of a broadcast packet or a multicast packet from one of the plurality of relay apparatuses having the grouped ports, add information indicative of a transmission source node of the broadcast packet or the multicast packet; and
wherein the processor further executes the instructions to control the plurality of relay apparatuses to perform packet forwarding of the broadcast packet or the multicast packet transmitted from the transmission source node using a broadcast path or a multicast path that prevents forwarding of the broadcast packet or the multicast packet from a port other than the selected representative port.

2. The control apparatus according to claim **1**, wherein the processor further executes the instructions to:
when the virtual logical link is set, control the plurality of relay apparatuses to perform packet forwarding using a broadcast path or a multicast path that prevents forwarding of the broadcast packet or the multicast packet from a port other than a representative port selected in advance among the grouped ports.

3. The control apparatus according to claim **1**, wherein the processor further executes the instructions to:
compute a broadcast path or a multicast path that prevents forwarding of a broadcast packet or a multicast packet from a port other than a representative port selected for the virtual logical link each time the virtual logical link is set, and
set in the plurality of relay apparatuses control information that causes the plurality of relay apparatus to perform packet forwarding along the broadcast path or the multicast path.

4. The control apparatus according to claim **1**, wherein the processor further executes the instructions to:
upon detection of a failure at the representative port, reselects a representative port from among the grouped ports, and controls a relay apparatuses having a port other than the reselected representative port so that a plurality of same packets are not forwarded to the plurality of physical links forming the virtual logical link.

5. A communication system, comprising:
the control apparatus as set forth in claim **1**, and a relay apparatus that is controlled by the control apparatus.

6. A communication method by a control apparatus comprising a topology management unit that manages a network topology formed by including a plurality of relay apparatuses, the communication method comprising:
grouping ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and managing the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;
controlling the plurality of relay apparatuses, having the grouped ports, so that when one of the plurality of relay

apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

computing a broadcast path or a multicast path that prevents forwarding of a broadcast packet or a multicast packet from a port other than a representative port selected for the virtual logical link each time the virtual logical link is set;

setting in the plurality of relay apparatuses control information that causes the plurality of relay apparatuses to perform packet forwarding along the broadcast path or the multicast path; and

managing a node connected through the virtual logical link to the plurality of relay apparatuses, having the grouped ports,

wherein depending on whether or not a transfer source of a packet is the managed node, the packet is determined to be a broadcast packet to be controlled or a multicast packet to be controlled.

7. A non-transitory computer-readable recording medium, storing a program for a computer constituting a control apparatus comprising a topology management unit that manages a network topology formed by including a plurality of relay apparatuses, the program causing the computer to execute:

grouping ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and storing the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;

controlling the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

computing a broadcast path or a multicast path that prevents forwarding of a broadcast packet or a multicast packet from a port other than a representative port selected for the virtual logical link each time the virtual logical link is set;

setting in the plurality of relay apparatuses control information that causes the plurality of relay apparatuses to perform packet forwarding along the broadcast path or the multicast path; and

managing a node connected through the virtual logical link to the plurality of relay apparatuses, having the grouped ports,

wherein depending on whether or not a transfer source of a packet is the managed node, the packet is determined to be a broadcast packet to be controlled or a multicast packet to be controlled.

8. A control apparatus, comprising:

a memory storing instructions; and

a processor that executes the instructions to:

manage a network topology formed by including a plurality of relay apparatuses:

group ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology;

manage the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;

control the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

wherein the processor further executes the instructions to, when the virtual logical link is set, control the plurality of relay apparatuses to perform packet forwarding using a broadcast path or a multicast path that prevents forwarding of the broadcast packet or the multicast packet from a port other than a representative port selected in advance among the grouped ports; and

compute a broadcast path or a multicast path that prevents forwarding of a broadcast packet or a multicast packet from a port other than a representative port selected for the virtual logical link each time the virtual logical link is set,

wherein the processor further executes the instructions to set in the plurality of relay apparatuses control information that causes the plurality of relay apparatus to perform packet forwarding along the broadcast path or the multicast path.

9. A control apparatus, comprising:

a memory storing instructions; and

a processor that executes the instructions to:

manage a network topology formed by including a plurality of relay apparatuses:

group ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology;

manage the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;

control the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

wherein the processor further executes the instructions to, when the virtual logical link is set, control the plurality of relay apparatuses to perform packet forwarding using a broadcast path or a multicast path that prevents forwarding of the broadcast packet or the multicast packet from a port other than a representative port selected in advance among the grouped ports; and

manage a node connected through the virtual logical link to the plurality of relay apparatuses, having the grouped ports,

wherein depending on whether or not a transfer source of a packet is the managed node, the packet is determined to be a broadcast packet to be controlled or a multicast packet to be controlled.

10. A control apparatus, comprising:

a memory storing instructions; and

a processor that executes the instructions to:

manage a network topology formed by including a plurality of relay apparatuses;

group ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and manages the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;

control the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

compute a broadcast path or a multicast path that prevents forwarding of a broadcast packet or a multicast packet from a port other than a representative port selected for the virtual logical link each time the virtual logical link is set;

set in the plurality of relay apparatuses control information that causes the plurality of relay apparatus to perform packet forwarding along the broadcast path or the multicast path; and

manage a node connected through the virtual logical link to the plurality of relay apparatuses, having the grouped ports,

wherein depending on whether or not a transfer source of a packet is the managed node, the packet is determined to be a broadcast packet to be controlled or a multicast packet to be controlled.

11. A control apparatus, comprising:

a memory storing instructions; and

a processor that executes the instructions to:

manage a network topology formed by including a plurality of relay apparatuses:

group ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology;

manage the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;

control the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

wherein the processor further executes the instructions to, when the virtual logical link is set, control the plurality of relay apparatuses to perform packet forwarding using a broadcast path or a multicast path that prevents forwarding of the broadcast packet or the multicast packet from a port other than a representative port selected in advance among the grouped ports; and

wherein the processor further executes the instructions to, upon detection of a failure at the representative port, reselect a representative port from among the grouped ports, and control a relay apparatuses having a port other than the reselected representative port so that a plurality of same packets are not forwarded to the plurality of physical links forming the virtual logical link.

12. A control apparatus, comprising:

a memory storing instructions; and

a processor that executes the instructions to:

manage a network topology formed by including a plurality of relay apparatuses;

group ports of the plurality of relay apparatuses, having a physical link with an arbitrary node of the network topology, and manages the grouped ports as a port of a virtual logical link between the plurality of relay apparatuses and the arbitrary node;

control the plurality of relay apparatuses, having the grouped ports, so that, when one of the plurality of relay apparatuses receives a broadcast packet or a multicast packet, a plurality of same packets are not forwarded to the physical links that form the virtual logical link;

compute a broadcast path or a multicast path that prevents forwarding of a broadcast packet or a multicast packet from a port other than a representative port selected for the virtual logical link each time the virtual logical link is set;

set in the plurality of relay apparatuses control information that causes the plurality of relay apparatus to perform packet forwarding along the broadcast path or the multicast path; and

wherein the processor further executes the instructions to, upon detection of a failure at the representative port, reselect a representative port from among the grouped ports, and control a relay apparatuses having a port other than the reselected representative port so that a plurality of same packets are not forwarded to the plurality of physical links forming the virtual logical link.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,407,503 B2
APPLICATION NO. : 14/376835
DATED : August 2, 2016
INVENTOR(S) : Nobuhiro Kusumoto

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page, Item (57), in the Abstract, line 12,
"plurality of same packet" should read --plurality of same packets--.

In the Claims

In claim 3, column 12, line 43,
"plurality of relay apparatus" should read --plurality of relay apparatuses--.

In claim 4, column 12, line 50,
"a relay apparatuses" should read --a relay apparatus--.

In claim 8, column 13, line 55,
"apparatuses:" should read --apparatuses;--.

In claim 8, column 14, lines 17-18,
"plurality of relay apparatus" should read --plurality of relay apparatuses--.

In claim 9, column 14, line 24,
"apparatuses:" should read --apparatuses;--.

In claim 10, column 15, line 7,
"plurality of relay apparatus" should read --plurality of relay apparatuses--.

In claim 11, column 15, line 22,
"apparatuses:" should read --apparatuses;--.

In claim 11, column 16, line 4,
"a relay apparatuses" should read --a relay apparatus--.

Signed and Sealed this
Twentieth Day of December, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

In claim 12, column 16, line 30,
"plurality of relay apparatus" should read --plurality of relay apparatuses--.

In claim 12, column 16, line 36,
"a relay apparatuses" should read --a relay apparatus--.